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Deep-Tow Acoustics/Geophysics System Compressional Velocity Database

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Abstract

This technical note describes the Deep-Tow Acoustics/Geophysics System (DTAGS) compressional velocity database, a compilation of compressional velocity functions derived from DTAGS deep-tow multichannel seismic data. Three geologically distinct areas are represented by the velocity functions included in this database: thick turbidites on the Bermuda Rise, fine grained terrigenous sediments containing methane hydrate on the Blake Outer Ridge, and thin sediments overlying young basement near the Juan de Fuca Ridge. Horizontal sampling frequency of the database ranges from 45 to 230 m. Vertical sampling frequency ranges from 20 to 300 m.

These compressional velocity profiles, functions of geographic region, layer thickness and range along the ship track, were determined from the DTAGS multichannel seismic data using standard semblance velocity analysis procedures. The six ASCII files containing compressional velocity data are included on an MS-DOS 3-1/2" diskette which may be ordered from the authors using the form included with this technical note. Included on the disk with the data files are two test files containing a description of the data file format and a list of the locations where the data were collected.

Acknowledgments

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Deep-Tow Acoustics/Geophysics System Compressional Velocity Database

Introduction

This technical note describes the high resolution Deep-Tow Acoustics/Geophysics System (DTAGS) compressional velocity database (which may be ordered on a diskette) and gives some guidelines for its use. The DTAGS compressional velocity database is a compilation of compressional velocity-thickness profiles derived from DTAGS multichannel seismic data. These data were collected between 1984 and 1990 on the Bermuda Rise, on the Blake Outer Ridge, and near the Juan de Fuca Ridge. The database consists of individual text files each containing compressional velocity-thickness functions derived from a single, continuous seismic line. Each velocity-thickness profile gives the compressional velocity as a function of depth (in terms of layer thickness, starting at the water-sediment interface) at a single location along the seismic line.

Horizontal sampling frequency of the velocity data ranges from 45 to 230 m, depending on the distance between gathers used in each velocity analysis. Vertical sampling frequency of the velocity data depends on the vertical spacing between the horizons used in the velocity analysis. Vertical resolution varies within a single data file due to lateral variability in the reflectivity along a single horizon and to rapid lateral changes in sediment structure. Velocity layer thicknesses resolved range from 20 to 300 m. The maximum depth of penetration depends on the subbottom sediment type and thickness and ranges from ~150 m near the Juan de Fuca Ridge to ~650 m on the Blake Outer Ridge.

Each file contains compressional velocity as a function of range and subbottom depth. The data in each individual file are derived from a single, continuous multichannel seismic data line, distinguished by location and geologic environment. The velocity files are written in ASCII format an MS-DOS 3-1/2" diskette which may be ordered from the authors using the order form included at the back of this technical note. This is the first in a planned series of seismoacoustic databases predicated on DTAGS data.

Methods

The velocity-thickness data were derived from multichannel seismic data collected using the Naval Research Laboratory's (NRL's) DTAGS system (Figure 1). DTAGS is a deep-towed multichannel seismic system in which the source and hydrophone array are both towed 350 to 450 m above the seafloor at depths up to 6000 m (Gettrust and Ross, 1990; Gettrust et al., 1991). The source is a Helmholtz transducer which generates a chirp from 250 to 650 Hz with peak output of ~205 dB. The receiver array consists of 24 hydrophone groups 21 m apart with a maximum offset of 620 m. Data are digitized at 3125 samples/s and telemetered to the ship via the coaxial tow cable. The true vertical position of the array is given by depth transducers located on the source and array.

The high frequency source gives DTAGS data vertical resolution of ~5 m. Lateral resolution of DTAGS data, as currently processed, is a function of the array length. Horizontal resolution as high as ~100 m can be achieved where laterally highly variable velocity or sediment structure need to be resolved.

The DTAGS data are processed using the following standard multichannel data processing procedures. Raw data are bandpass filtered from 250 to 650 Hz. The data are correlated with a calibrated reference trace to collapse the 250 - 650 Hz source chirp to a Ricker-type wavelet. Zero phase deconvolution is performed to reduce wavelet sidelobes.

Though, ideally, the array should remain perfectly horizontal as it is towed through the water, the array generally tilts 0° to 11° from horizontal. Static time shifts to compensate for this array tilt are determined from the difference between the source depth and the depth of the array, as given by the depth transducers. These static shifts are applied to the traces to compensate for deviation of the array from horizontal.

Next, stacking velocities, compressional velocities averaged over the paths travelled by the signal (Al-Chalabi, 1974), are determined from the multichannel data. These stacking velocity estimates are made using semblance velocity analysis. Highest semblance is obtained for the best estimates of average velocity. At these velocities the horizons corrected for normal moveout (NMO) are flat across a gather. The multichannel data are then stacked to check the accuracy of the stacking velocities. Where stacking velocity estimates are poor, horizons lose coherence in the stacked section. Stacking velocity profiles are refined at the locations where the velocity estimates looked poor and the section is re-stacked. If the best estimate stacking velocity profile still stacks the data incoherently, that stacking velocity profile is deleted.

After the stacking velocities are refined, Dix's (1955) equation is used to convert the stacking velocity profiles to interval compressional velocity profiles. These interval velocity profiles are checked by converting the seismic data from time to depth. The appearance of structural features and discontinuities in the seismic depth section that are inconsistent with the sediment structure shown in the time section indicate the interval velocities at these locations are incorrect. These interval velocity profiles are deleted from the database.

Areas Covered

Three geologically distinct areas are represented by the compressional velocity data included in this database: thick turbidite sequences (Bermuda Rise), thick sequence of fine grained terrigenous sediments containing methane hydrate (Blake Outer Ridge), and thin sediment overlying young basalt basement (Juan de Fuca). Table 1 lists the specific areas, by latitude and longitude, covered by the database.

Bermuda Rise

File *bermuda1* contains a series of one-dimensional compressional velocity profiles obtained from a ~3 km seismic line trending north-south on the Bermuda Rise in the North Atlantic Ocean (Figure 2, Table 1). The seismic data (Figure 3) resolve a ~450 m thick sequence of sediments consisting of middle Eocene to Oligocene turbidites overlain by Miocene to Quaternary age pelagic sediment (Tucholke et al., 1979; Gettrust et al., 1988; Bowles et al., 1991).

Table 1
Locations of DTAGS Compressional Velocity Data

environment	file name	location	comments
thick turbidite	bermuda1	30°53'N,66°08'W- 30°55'N,66°07'W	
thick terrigenous sediment	blake1	30°41'N,75°32'W- 30°39'N,75°32'W	methane hydrate present
thick terrigenous sediment	blake2	30°41'N,75°32'W- 30°40'N,75°38'W	little methane hydrate
thin sediment	juan1b	45°28'N,128°45'W- 45°26'N,128°45'W	parallel to Juan de Fuca Ridge
thin sediment	juan2b	45°25'N,128°45'W- 45°24'N,128°45'W	1.5 km south of juan1b, crosses juan3b at 0.3 km
thin sediment	juan3b	45°25'N,128°44'W- 45°25'N,128°47'W	crosses juan2b at 0.2 km

Blake Outer Ridge

File *blake1* contains a series of velocity profiles obtained from a ~2.5 km seismic line trending north-south on the Blake Outer Ridge in the North Atlantic Ocean (Figure 4, Table 1). The seismic data (Figure 5a) resolve ~650 m of hemipelagic silty clay (Hollister et al., 1972; Sheridan et al., 1983) deposited by contour currents (Markl and Bryan, 1983). A bottom simulating reflector (BSR) occurs at ~650 m depth in the sediment marking the base of a 400 m thick layer containing a high concentration of methane hydrate (Paull and Dillon, 1981; Rowe and Gettrust, 1991a).

File *blake2* contains a series of velocity profiles from a ~7.9 km line running from west to east across the Blake Outer Ridge (Figure 4, Table 1). These profiles are 5 km west of the data in file blake1, in the same geologic environment (Figure 5b). These profiles extend to only ~425 m due to the lack of a BSR or other deeper horizons to enable velocity analysis to be performed. Absence of a BSR and generally lower compressional velocities in these sediments indicate that little methane hydrate is present in these sediments (Rowe and Gettrust, 1991a).

Juan de Fuca

File *juan1b* contains a series of compressional velocity profiles obtained from seismic data collected in the North Pacific Ocean along a 3.0 km line running parallel to the Juan de Fuca Ridge, ~95 km from the ridge (Figure 6, Table 1). Sediment in this area is 100 to 150 m thick, overlying young basalt basement (Figure 7a). This thin sediment layer is made up of thinly bedded, flat lying turbidites overlying rough basalt basement (Carson, 1973). The compressional velocity profiles in this area are characterized by a low velocity zone in the upper 50 m of sediment (Rowe and Gettrust, 1991b). No velocity estimates from the basalt were obtained due to the roughness of the basement.

File *juan2b* contains a series of velocity profiles from a continuation of the seismic data used to obtain the compressional velocity estimates in *juan1b*, 1.5 km to the south (Table 1). These velocity profiles were obtained from a ~1.5 km long seismic line running from north to south. The geologic structure (Figure 7b) is a continuation of the turbidites observed in the seismic section to the north.

File *juan3b* contains velocity profiles obtained from a seismic line perpendicular to *juan2b* (Table 1) trending from east to west. The two profiles cross at 0.3 km on juan2b and 0.2 km on juan3b, as shown by the arrows in Figures 7b and 8. There is no change in the sediment structural grain along this orthogonal profile (Figure 8).

Database Format

The compressional velocity-thickness data are written as text files on a 3-1/2" high-density MS-DOS diskette. These text files may be read on any IBM-PC compatible system running MS-DOS using the "type" command. All velocity data files are displayed on the screen in the format shown in Table 2.

Each row on Table 2 represents a single formatted record. The first record in the file lists the name(s) of the original data file(s) from which the velocity data that follow were derived. The second record in the text file (Table 2) gives the number of one-dimensional compressional velocity profiles included in the data file. The total number of profiles in a data file, dependent on the length of the seismic line from which the data were derived and the spacing between velocity semblance analyses, is different for each file. The compressional velocity-thickness profiles follow these two file headers (Table 2). Each profile header, the first record in the velocity profile, gives the location of the profile along the seismic line (the start of a given seismic line is always at 0.0 km) and the number of thickness-velocity pairs within that profile (Table 2). The number of thickness-velocity pairs within each profile will vary from profile to profile within a single data file.

Repeat value, given in the left column, is the number of times this entry type (file header, profile header, etc.) is repeated within a velocity file. For example, if there are *n* profiles in a given file there will be *n* sets of a profile headers followed by the thickness-velocity pairs in the file. If there are *i* thickness-velocity pairs in a given profile there will be *i* records containing thickness and velocity following that profile header.

Data formats given in Table 2 use standard FORTRAN descriptors. Range of the profile along the seismic line and layer thickness are given in meters, compressional velocity is given in meters/second. Table 2, the data format description, is included on the diskette with the data files as file *format*. Table 1, giving the locations where the data sets were collected, is also on the disk, file *directry*.

Table 2
Compressional Velocity Data File Format

repeat value	format	description
1	character*64	file header 1 - name(s) of source file(s) for velocity profiles
1	i3	file header 2 - *n*, the number of velocity profiles in this file
n	f8.2, i3	profile header 1 - range of profile 1 from start of line and *i*, the number of thickness-velocity pairs in this profile
i	f8.2, f8.2	thickness in layer 1, velocity in layer 1
		. . .
	f8.2, f8.2	thickness in layer *i*, velocity in layer *i*
. . .	. . .	. . .
	f8.2, f8.2	profile header *n*, range of profile *n* from start of line and *k*, the number of thickness-velocity pairs in this profile
k	f8.2, f8.2	thickness in layer 1, velocity in layer 1
		. . .
	f8.2, f8.2	thickness in layer *k*, velocity in layer *k*

Guidelines for Modelling

Acoustic Models

Acoustic models require compressional velocity and density estimates as input. Signals are reflected where there is an abrupt change in sediment impedance, which is dependent on density and velocity. High resolution compressional velocity functions can be obtained directly from the DTAGS compressional velocity database for those areas covered (Table 1).

Though signal phase and partitioning of the reflected energy appear to be relatively insensitive to sediment density, results from DTAGS data analysis indicate that reflection strength is highly sensitive to changes in density. For this reason it is important that the density input to the acoustic model is accurate (Gettrust and Rowe, 1991). Estimates of in situ sediment density can be obtained from the Deep Sea Drilling Project reports from sites 386 and 387 (Tucholke et al., 1979) for the Bermuda Rise region and from sites 102, 103, 104 (Hollister et al., 1972), and 533 (Sheridan et al., 1983) for the Blake Outer Ridge region. Approximations of density as a function of depth can be obtained from Hamilton's (1980) density functions, from the Nafe-Drake density curves (Nafe and Drake, 1963), or from the Gardner et al. (1979) density function.

Elastic Models

Elastic models require estimates of shear velocity and anelastic attenuation as input, as well as to compressional velocity and density. DTAGS data have been analyzed to obtain estimates of shear velocity within the upper ~50 m of seafloor sediment. Results show that shear velocity in these sediments is low, ~100 to ~300 m/s on the Bermuda Rise, with Poisson's ratio ~0.48 (Gettrust and Rowe, 1991). On the Blake Outer Ridge, shear velocities in the upper ~40 m of sediment are usually less than ~200 m/s with limited regions where shear velocity reaches 500 to 600 m/s (Lindwall and Getrust, in preparation).

Estimates of shear velocity as a function of depth for deeper (>50 m) sediments and for the Juan de Fuca Ridge sites can be obtained from Hamilton (1980). The low compressional velocities of the Juan de Fuca Ridge sediments and the high Poisson's ratio observed in the sediments in the other regions suggests shear velocity within these sediments will also be on the order of 100 to 300 m/s. More detailed shear velocity estimates will be available as more data are processed.

Estimates of anelastic attenuation should be constrained by the known sediment compressional velocity, density, and shear velocity and by the sediment type in a given area. Empirical estimates of attenuation as a function of depth may be obtained from Hamilton (1980) for a variety of sediment types and geologic environments. Wrolstad (1980) gives experimentally derived attenuation values for marine sediments near the Juan de Fuca Ridge. Our limited modelling efforts indicate that model results are not sensitive to attenuation.

Summary

The DTAGS compressional velocity database contains compressional velocities as a function of geographic region, range, and depth (in terms of layer thickness) within the sediment. These compressional velocity profiles were derived from DTAGS multichannel seismic data using standard multichannel seismic processing techniques. Three geologically distinct regions are represented in the database: thick terrigenous turbidites, thick fine grained sediment containing methane hydrate, and thin sediment over young oceanic crust. The data files are written in ASCII text format on a 3-1/2" high-density MS-DOS diskette. The compressional velocities from this database may be used directly as input to acoustic models, providing reasonable estimates of density are also made. Elastic models require shear wave velocity and attenuation input as well as compressional velocity and density in order to accurately model the elastic subbottom response.

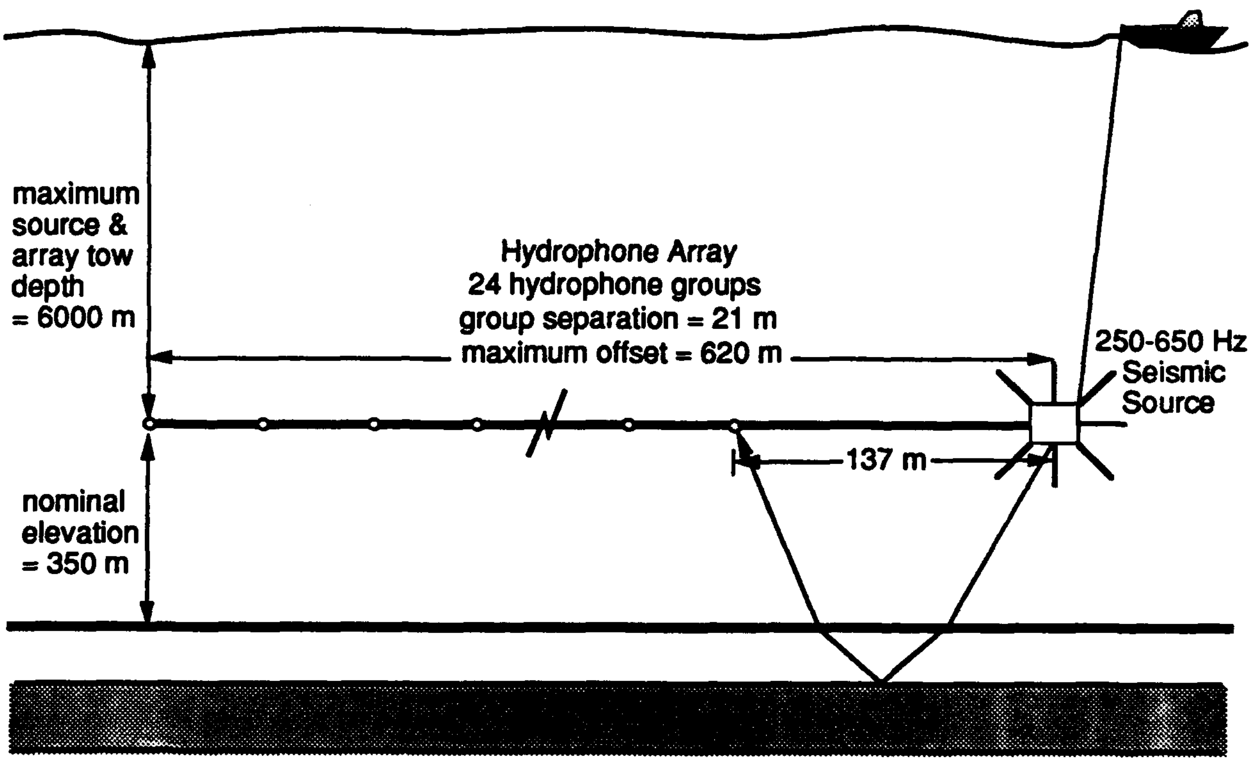

Figure 1. DTAGS instrument configuration showing the source and array geometry and proximity to the bottom when deployed.

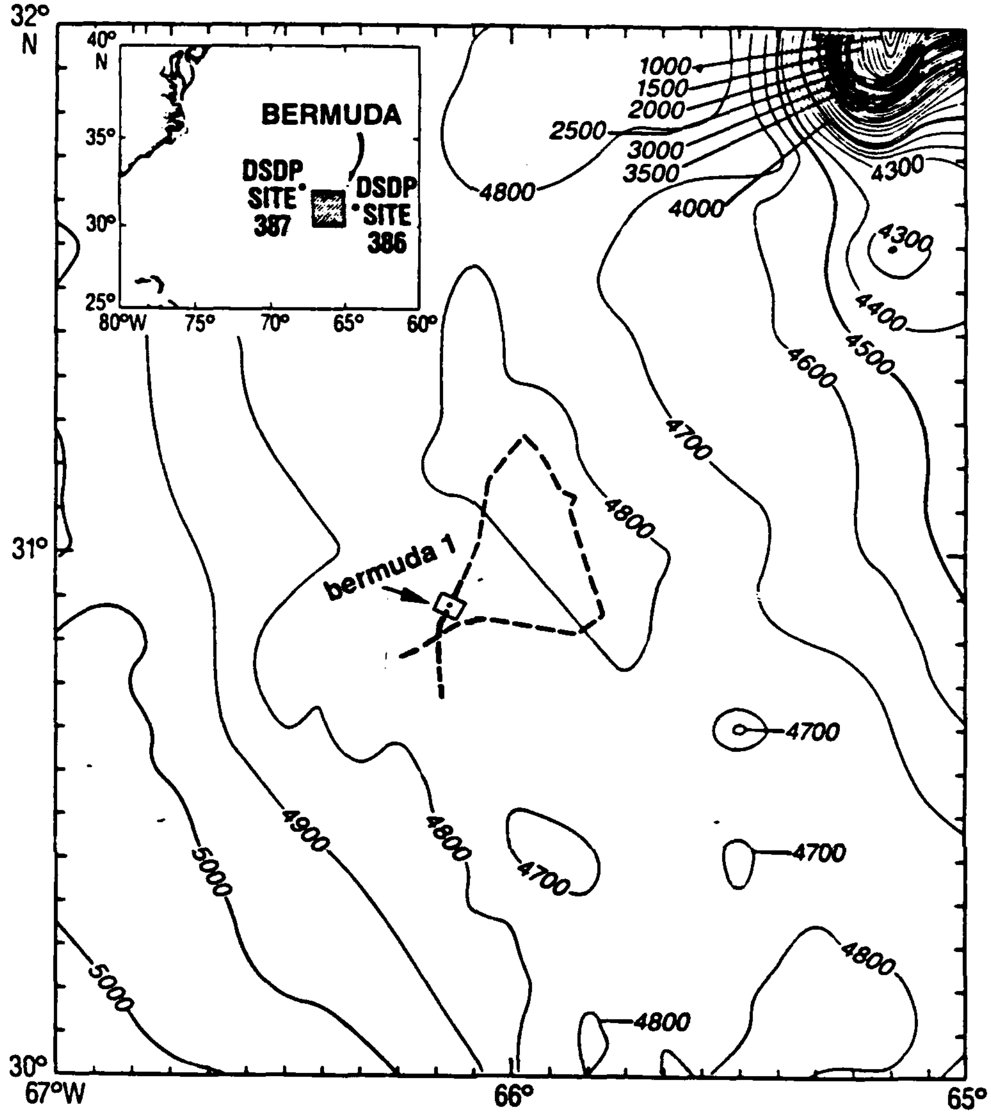

Figure 2. Map showing the location of the velocity profiles in file *bermuda1*. The dashed line is the entire ship track during the experiment.

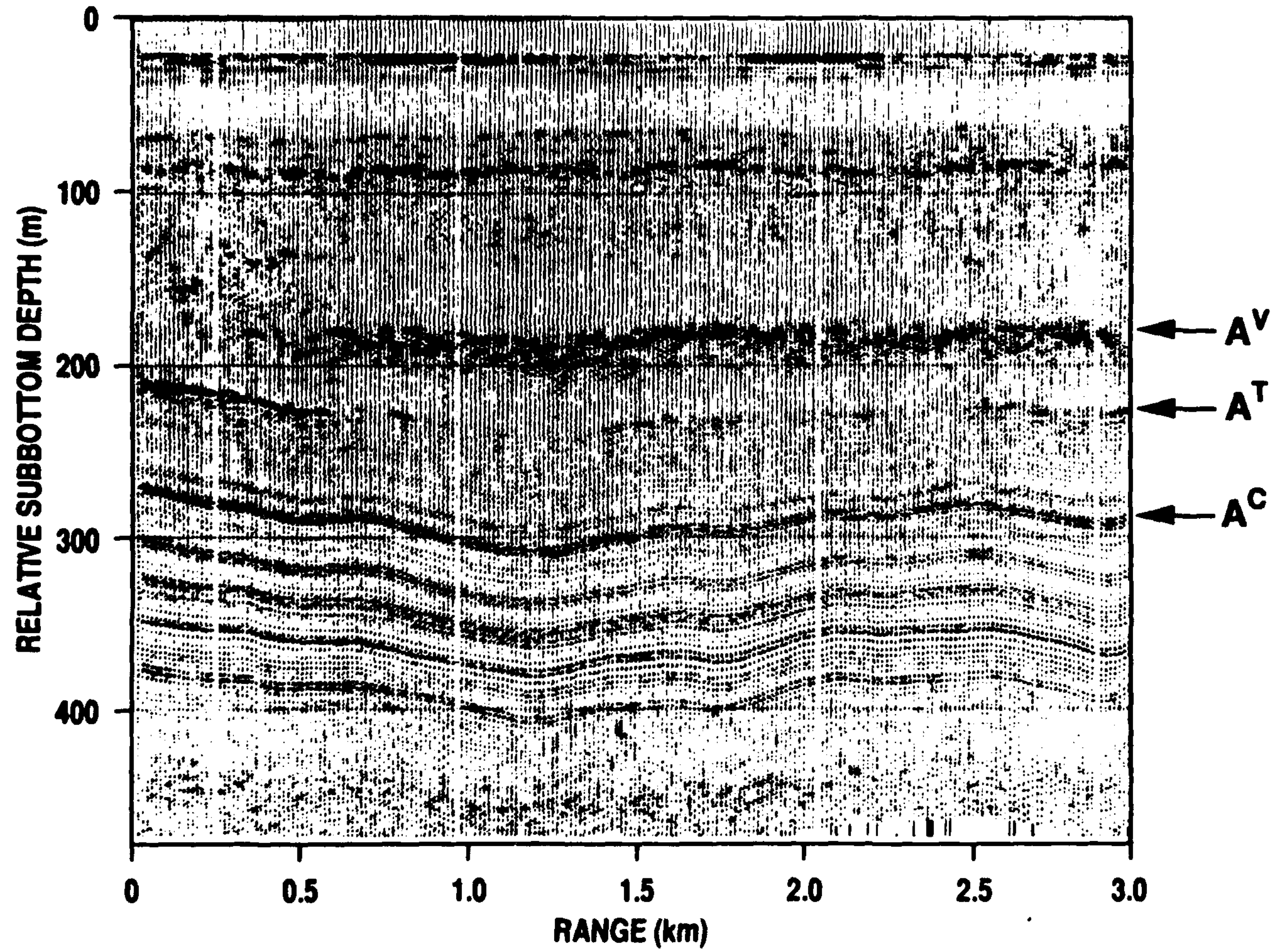

Figure 3. Twenty-four-fold stacked multichannel seismic section of the data from the Bermuda Rise used to obtain the compressional velocity estimates in *bermuda1*. A^T, A^V, and A^C, are turbidite layers identified by Tucholke and Mountain (1979).

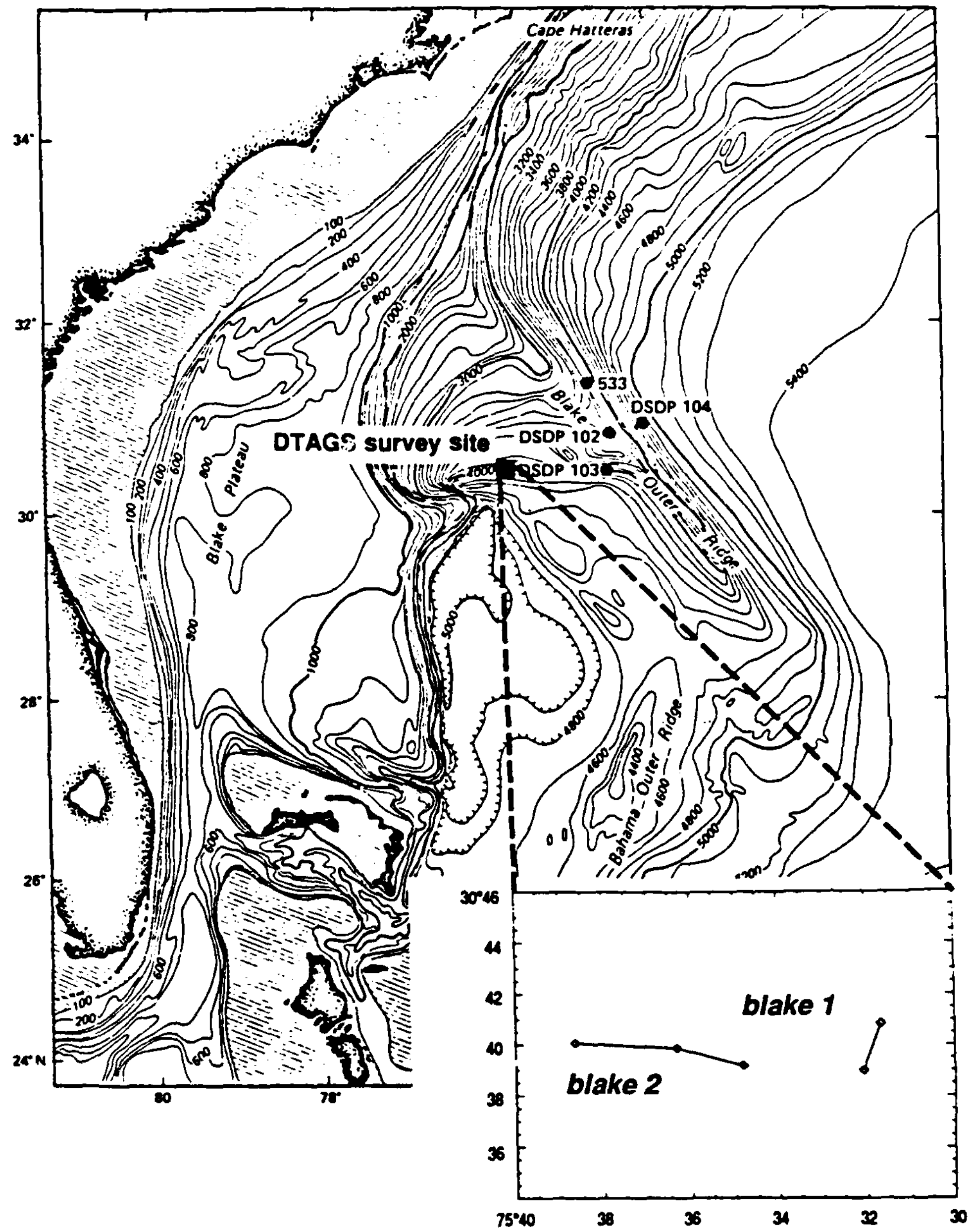

Figure 4. Map showing the location of the velocity profiles in files *bla!el* and *blake2*.

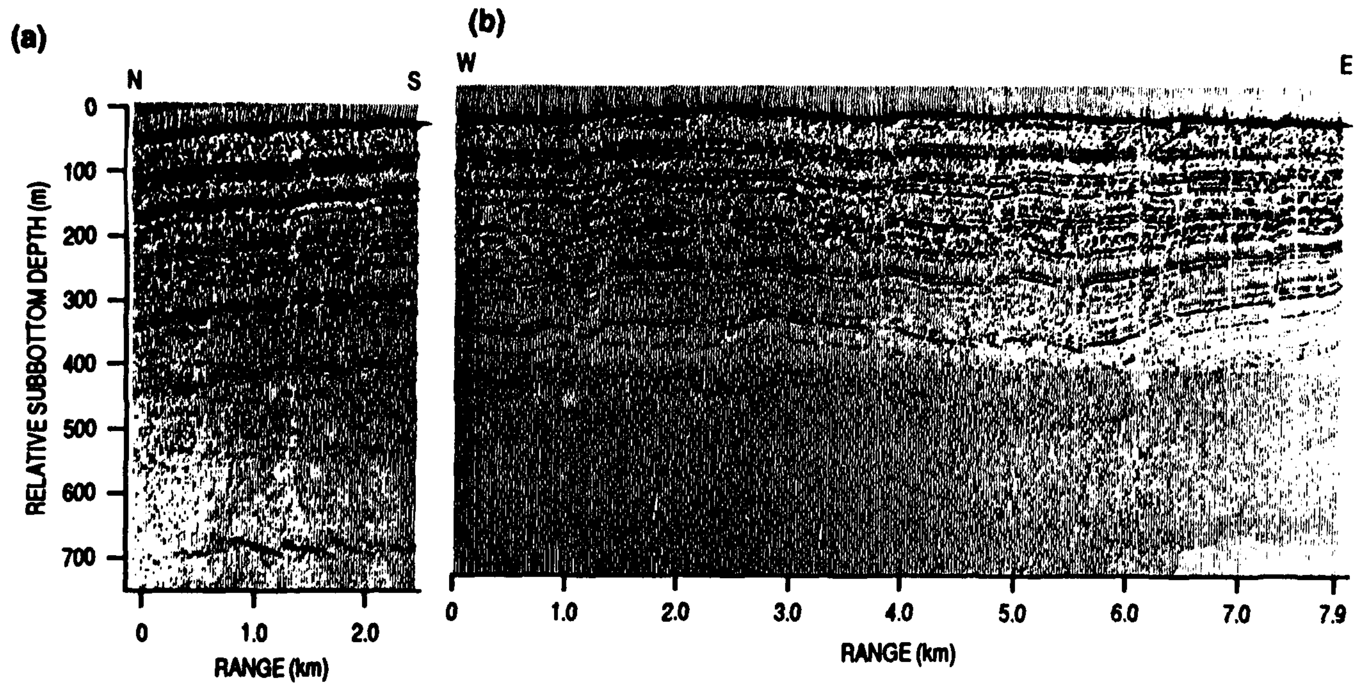

Figure 5. (a) Single channel, near trace seismic section from the data used to obtain the velocity estimates in *blake1*. The BSR occurs at ~700 m depth.
(b) Single channel, near trace seismic section from the data used to obtain the velocity estimates in *blake2*.

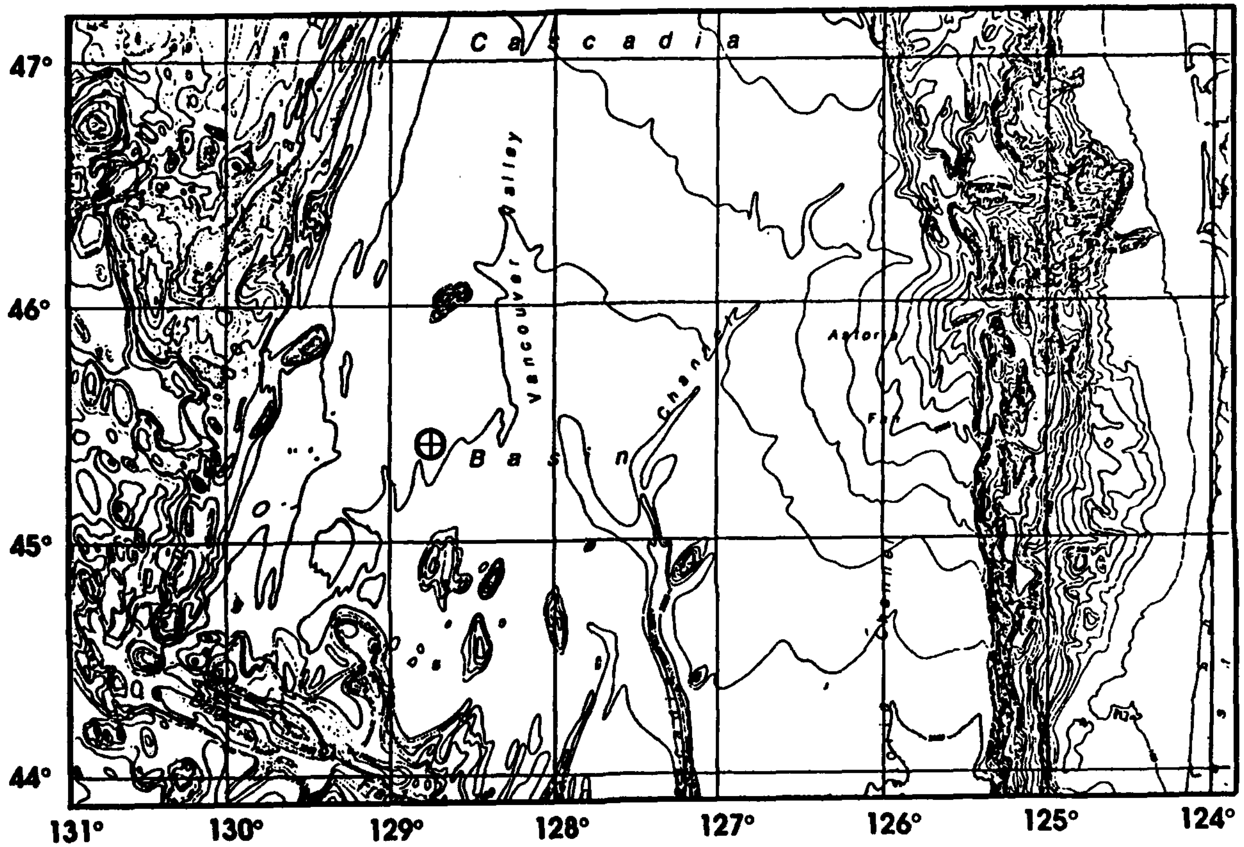

Figure 6. Map showing the location of the velocity profiles in files *juan1b*, *juan2b*, and *juan3b*.

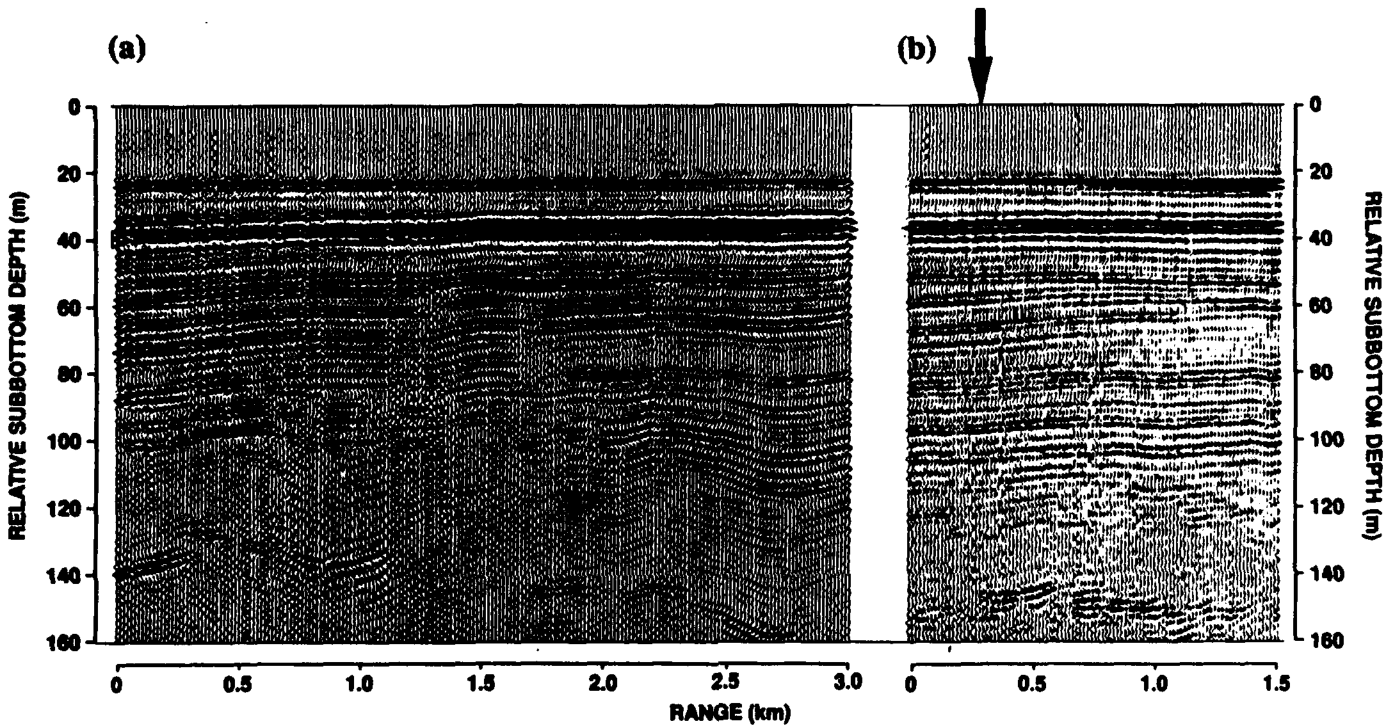

Figure 7. (a) Twenty-four-fold stacked multichannel seismic section of the data used to obtain velocity estimates in *juan1b*. (b) Twenty-four-fold stacked multichannel seismic section of the data used to obtain velocity estimates in *juan2b*. Thinly bedded turbidite layers correlate exactly from (a) to (b). Arrow shows where this line crosses the line shown in Figure 8.

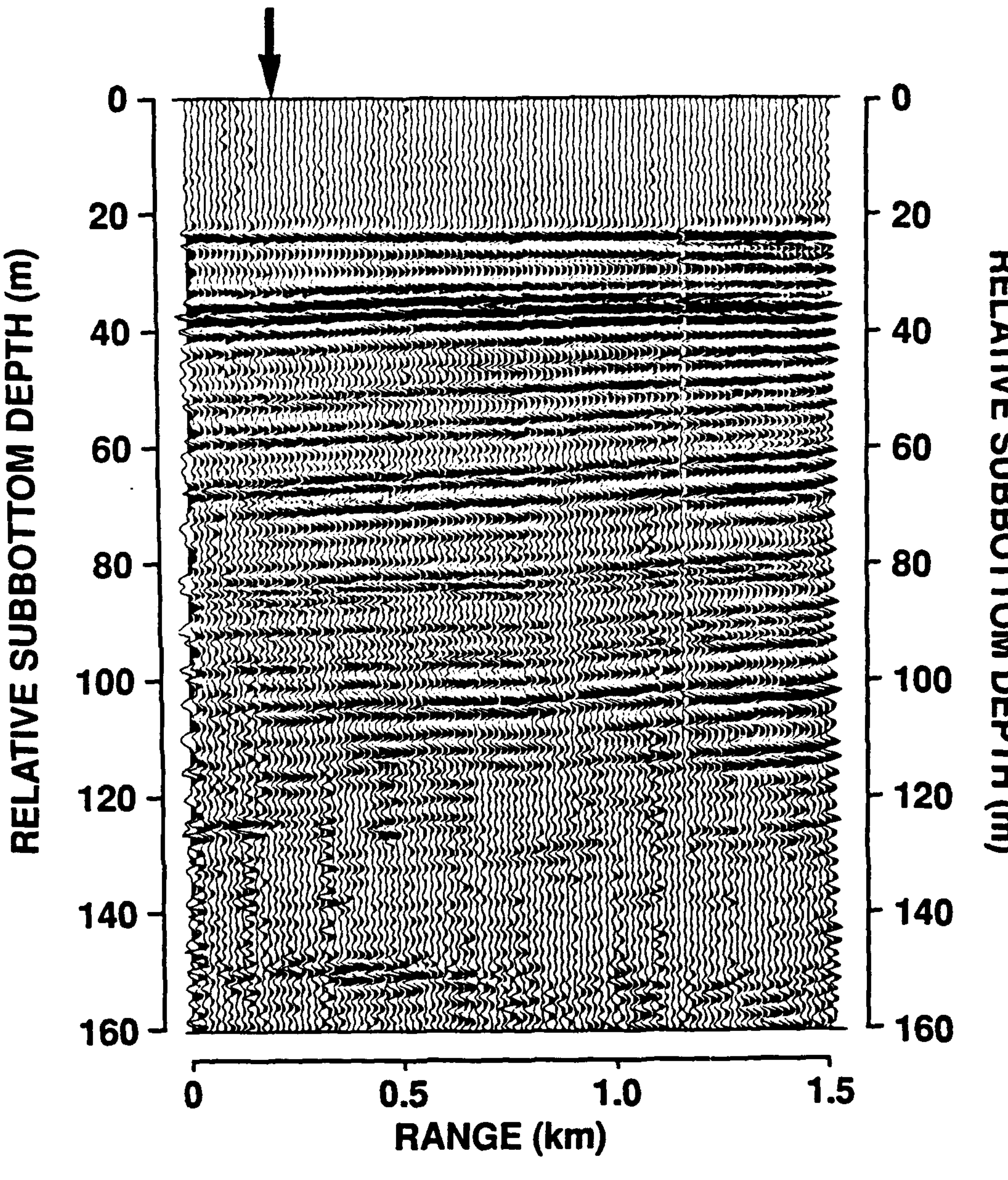

Figure 8. Twenty-four-fold stacked multichannel seismic section from data used to obtain velocity estimates in file *juan3b*. Arrow indicates where this line crosses the line shown in Figure 7b.

ORDER FORM

To receive a copy of the 3-1/2" high density MS-DOS diskette containing the DTAGS compressional-velocity data files described in this Technical Note you may use this form:

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Address ____________________________________

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